DEVELOPMENT OF A SEMI-AUTOMATED ON-THE-ROAD PAINTING MACHINE

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To

My loving mother,
A strong and gentle soul who taught me to trust in
Allah and believe in hard work.

My idol father,
For showing me all the wonders in life
and preparing me for the hurdles that comes along.

My beloved family,
For being there no matter what happens
Because family will always be family.

ABSTRACT

Currently, the widely used machines for painting road lanes in Malaysia are manually operated. The nature of the operation is not only labour-intensive but also time-consuming. Furthermore, the operator is being constantly exposed to high risk situations such as potential hazard inflicted by hot-melted paint and collision with passing vehicles especially on heavily used road. To overcome these issues and yet maintaining the operational cost lowest as possible, this project is aimed to design and develop a semi-automated road lane painting system comprising of an automated paint delivery mechanism that is capable of producing different line patterns on a road surface mounted on a mobile platform and attached to an electric bicycle as the prime mover. The automated paint delivery mechanism is designed using a mechatronic approach. An *Arduino* microcontroller is employed to automate the sequences of operations of various devices by means of a computer program controlled by human via a remote control device (touch screen). A safety lamp and a camera with a reasonably large *Liquid-Crystal Display* (LCD) screen are incorporated into the system as additional commercially attractive features. A crude work prototype of the semi-automated road lane painting device was developed and experimentally tested on actual road conditions. The results indicate that the system can perform the basic task; however, the quality of the painted lines requires further improvement. As such, the potential commercial value of the proposed and crudely developed semi-automated road lane painting system may trigger considerable interest in both the academic and industrial sectors.

ABSTRAK

Pada masa kini, kebanyakan mesin yang digunakan untuk mengecat jalan di Malaysia dikendalikan secara manual. Sifat pengoperasiannya bukan sahaja memerlukan kepada tenaga buruh yang berat malah memakan masa yang panjang untuk diselesaikan. Tambahan lagi, pengendali mesin mengecat akan senantiasa terdedah kepada bahaya berisiko tinggi seperti kesan melecur terkena cat cairan panas dan perlanggaran dengan kenderaan lalulintas terutamanya ketika jalan sesak. Bagi mengatasi masalah ini dan disamping mengekalkan kos operasi secara serendah yang mungkin, projek ini dijalankan bertujuan untuk menghasilkan sebuah sistem mengecat jalan semi-automatik yang terdiri daripada mekanisma cat penghantaran automatik yang mampu menghasilkan corak garis yang berbeza pada permukaan jalan yang dipasangkan pada sebuah platform bergerak yang bersambung dengan sebuah basikal elektrik sebagai pengerak utama sistem. Mekanisma penyampaian cat automatik ini direka bentuk menggunakan pendekatan mekatronik. *Arduino* sebuah alat mikropengawal digunakan untuk mengautomasi urutan operasi pelbagai alat dengan menggunakan program komputer yang dikawal oleh manusia melalui alat kawalan tangan (skrin sentuh). Sebuah lampu keselamatan dan kamera bersama dengan skrin *Liquid-Crystal Display* (LCD) dimasukkan ke dalam sistem sebagai ciri-ciri komersial tambahan. Sebuah protototaip sistem mengecat jalan semi-automatik yang kasar telah dihasilkan dan diuji secara operasi eksperimen di atas keadaan jalanraya yang sebenar. Keputusan eksperimen menunjukkan bahawan sistem mampu untuk menjalankan tugasan asas akan tetapi garisan cat yang dihasilkan masih memerlukan penambahbaikan dari segi kualiti. Oleh itu, potensi nilai komersial penghasilan sistem semi-automatik mesin mengecat jalan secara kasar ini dianggap mampu untuk menarik minat kedua - dua sektor akademik dan industri

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LIST OF ABBREVIATIONS

App	-	Application
CAD		Computer Aided Design
DC	-	Direct Current
GND	-	Ground
I/O	-	Input and Output
JKR	-	*Jabatan Kerja Raya*
LCD	-	Liquid-Crystal Display
m	-	Metre
ml	-	Millilitre
mm	-	Millimetre
N	-	Newton
PC	-	Personal Computer
PDS	-	Product Design Specification
PIC	-	Peripheral Interface Controller
PLC	-	Programmable Logic Controller
R×D	-	Receive Data
SIRIM	-	Scientific and Industrial Research Institute of Malaysia
T×D	-	Transmit Data
V	-	Voltage
Vcc	-	Voltage at the Common Collector

LIST OF SYMBOLS

℃	-	Celsius
%	-	Percentage

CHAPTER 1

INTRODUCTION

1.1 General Introduction

In modern days, means of transport on land had evolved from walking, riding animals, riding bicycles to petrol-powered vehicles such as motorcycles, cars, buses, and trucks. To improve travelling time from one location to another, pavement road was introduced. One of the well-known modern road construction techniques was first developed by John McAdam, a Scottish engineer, in the early 19th century (Abrams, 2013) involving the layering of roadbeds consisting of soil and cluster of crushed stones that were compacted by means of an impacting machine or a heavy roller. This fundamental technique was improved in the 20th century by the addition of tar as binder to produce concrete pavements referred to as bitumen or asphalt roads. The ease of mobility on asphalt roads had continued to enhance the economic development and standard living of a country.

A major drawback of the increase in speed of travelling on land is the increase in accident not only between vehicles and but also between vehicles and pedestrians. Some of the collisions may result in grave consequences. As such, one of the ways to minimize accident and maintain efficiency of the flow of traffic is by having appropriate markings or lines on concrete pavements. In Malaysia, there are three types: longitudinal, transverse, and other special lines. These are usually made with the use of special paints, liquid or thermoplastic types, that concur with the regulation of department of public safety and other governing institutions related to the transport system in Malaysia. For temporary markings, preformed tapes are used.

According to Ali *et al.* (2016), the process of conventional road painting in Malaysia can be divided into two main tasks. The first is to determine the exact position of a lane at the early stage by performing a pre-sketch marking onto the road surface. This is done manually as shown in Figure 1.1(a). The second is to spray or discharge the paint onto the pre-sketch mark. This is also done manually as shown in Figure 1.1(b).

(a)

(b)

Figure 1.1: Typical road painting process (a) pre-marking (Nanjing Roadsky Traffic Facility Co., Ltd., 2015) (b) paint discharging

Both processes are time-consuming and labor-intensive. They require blocking of road for hours which may cause serious traffic jam on heavily used road. Furthermore, the workers are being exposed to potential hazard of hot-melted paint and collision with passing vehicles (Woo *et al.*, 2008). As road lanes are imperative to maintain safety and efficiency of traffic flow, road painting is a necessary operation not only for newly developed roads but also for old roads with faded lanes. As such, another problem of manual road lane painting is that the nature of the operation demands skill and experienced workers (Kotani *et al.*, 1994).

One of the promising ways to overcome potential work hazard and likely to enhance painting operation efficiency is by automating the whole painting process. However, a fully automated lane marking operation using robot has several drawbacks. A research done by Thomson and Baltes (2001) explained that the problems with mobile autonomous robots are that they are expensive (especially the sensors and processors) and not versatile. These robots require precise and specific information before any execution of a task can be performed. Hence, considerable processing resources are required to maintain the quality of a task. If the condition is not suitable for the robot processing requirements, then the autonomous robot will be deemed inapplicable for that task. Thus, as a mean to overcome these setbacks is to develop a semi-automated painting system for road lane painting.

1.2 Objectives of Study

The objective of this study is to design and develop a practical road lane painting machine attached to an electrical driven vehicle. The machine is capable to produce different patterns in the middle of the road whether it is a single line or double lines which can be continuous or interval painting based on designed algorithms using a combination of different open softwares controlled by an operator. The performance of the proposed semi-automated road lane painting machine will be evaluated experimentally using liquid paint.

1.3 Scope of Study

The scope of the study is divided into two parts. The first part is to design a conceptual road lane painting machine that will cater to the conditions of a single straight line or double straight lines according to a design flow procedure that will be explained in Chapter 3. The human-operated machine will be developed using suitable actuating devices. Microcontroller with suitable software driver will be applied to control the device actuator(s). The second part is to evaluate the design of the road lane painting machine for testing in the middle of the road limited to produce a straight single or double straight lines road lane patterns that are either continuous or interval. The drawn road lane pattern by the machine must comply with the standards set by the *Jabatan Kerja Raya* (JKR) Malaysia. Liquid paint that is white in colour will be used to test the workability of the proposed painting mechanism. Experimental analysis to determine suitable paint mixture for effective painting (distribution & sharpness) shall also be carried out.

1.4 Project Approach

A project approach as shown in Figure 1.2 had been planned at an early stage. The process starts with the development of conceptual design ideas of the system. The ideas are based on literature reviews (Chapter 2). By using decision making steps of analysis, a final design model is determined and a 3D model of the painting mechanism is developed using *Computer Aided Design* (CAD) software. The model is tested under simple actuation simulation for functionality validation.

The model is then fabricated, assembled, and mounted onto an electrically driven vehicle. Experimentation is carried out to test the functionality of the algorithm designed for the system. Next, performance analysis evaluation is carried out using actual liquid paint on the system. The first step is to test the painting mechanism with paint mixture of different diluted percentage. The purpose of this step is to find the best suitable paint mixture for effective painting of an area. The best paint mixture is then used to evaluate the performance of the road lane painting

machine in producing other road lane patterns. Subject to some modification, if any, and the experimental procedure is repeated.

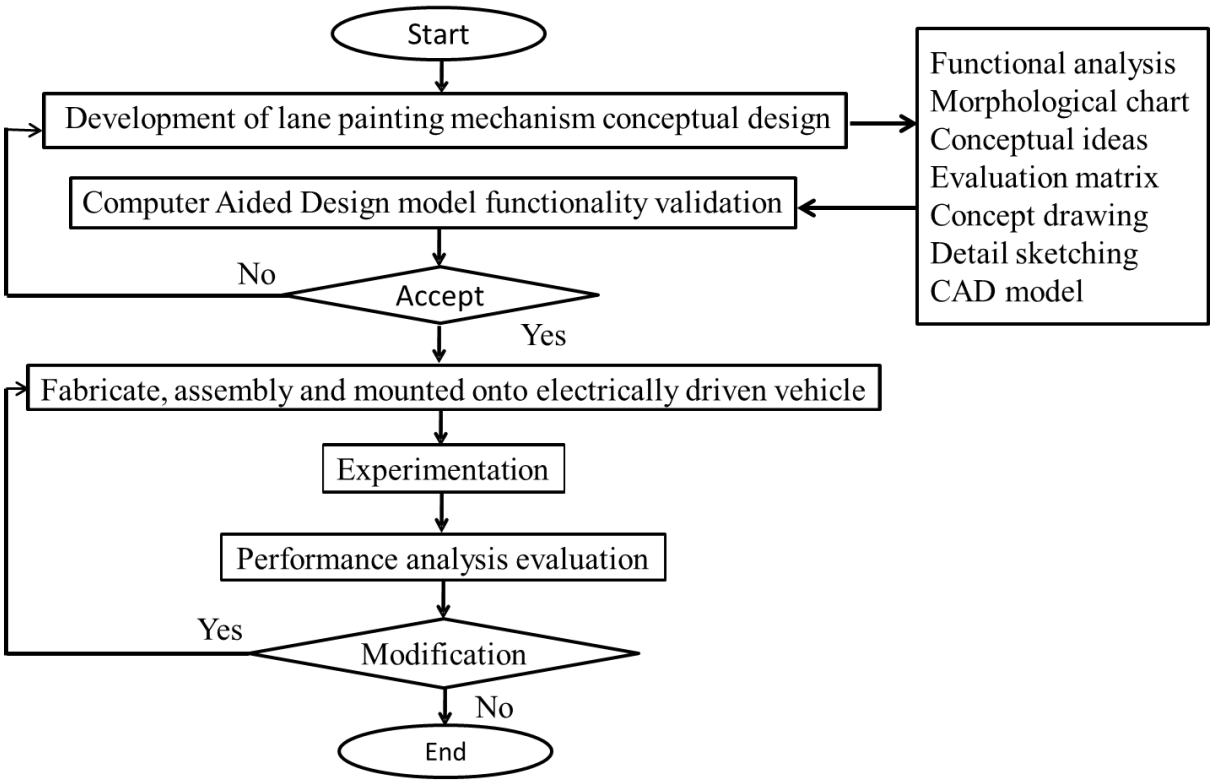

Figure 1.2: Project approach flowchart

1.5 Outline of Report

This report is divided into five chapters. Chapter 1 presents the introduction of the study including objective, the scope of the study and the project approach. Chapter 2, reviews on the existing road painting machines and past pattern designs, including JKR Malaysia road lane specifications.

Chapter 3 is about the development of the painting mechanism that will be mounted onto a mobile platform. This is in fact the main chapter that describes the essence in designing and developing the complete proposed system. The integration of all relevant components and experimental test and evaluation are fully explained in Chapter 4. The chapter also involves the incorporation and installation of extra

features of other components besides the painting system in the form of safety items. All of the devices are controlled by using a microcomputer based controller with the assistance of a built smartphone application (app) as the remote controller which results in the development of a semi-automated system. Upon doing the experimental test and evaluation of the developed system, some necessary modifications to the system were made, particularly in the physical design and fabrication of the mechanical parts to improve the system performance. Finally, this project is concluded in Chapter 5 with a number of recommendations for future works highlighted.

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